Spatially Resolved Spectroscopy to Probe Disk Composition and Structure

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Spatially resolved spectroscopy of circumstellar disks can clarify the temperature, density, and material composition of disks in their planet forming stages. We present spatially resolved spectra of three disks: mid-infrared spectra of HD 141569A and β Pictoris and visual spectra of TW Hya. HD 141569A is a 5 Myr old A0 star whose disk is in transition from a gas-rich proto-planetary state to a gas-poor debris state. Prior imaging has shown that hot grains can be resolved out to 150 AU ($1\farcs5$) from the star; the disk is detected in spectra taken with the Long Wavelength Spectrograph at the W.M. Keck Observatory out to 100 AU. PAH features at 8 and 11.7 μm, whose ratios change as a function of radius, plus a featureless continuum are seen. Conspicuous in their absence are any signs of silicates. β Pictoris is a 12 Myr old A4 star whose disk is composed of debris. Within 20 AU of the star, the mid-infrared spectrum, also from Keck, is dominated by amorphous and crystalline silicates. Farther out, the disk spectra are featureless and are entirely dominated by dust thermal continuum emission. The outer radius of the silicates is coincident with a warp in the disk seen in 12 and 18 μm imaging. A large collision rate in the inner part of the disk, perhaps instigated by a planet, can explain why the small (micron-sized) grains are found there. TW Hya is an 8 Myr old K7 star. Classified as a classical T Tauri star, it shows weak mass accretion and its optically thick disk contains significant gas and dust. We have used the STIS instrument aboard HST to make spectra of the face-on disk. After careful subtraction of a PSF star spectrum, scattered light from the disk can be traced from about 35 AU to 173 AU from the star. The scattered light has the same color as the star (gray scattering) at all radii beyond about 50 AU. However the scattered light at 40 AU is blue compared to the star. This likely indicates that the scattering dust grains are much larger than 1 μm throughout the bulk of the disk, but very small grains populate the central region.